HUMAN RETURN TO THE MOON: A MARS FORWARD ANALOG STRATEGY FOR LUNAR SCIENCE AND EXPLORATION. Pascal Lee[1,2,3], [1]Mars Institute, [2]SETI Institute, [3]NASA Ames Research Center, Moffett Field, CA 94035-1000, USA. E-mail: pascal.lee@marsinstitute.net.

Introduction: As humans prepare to return to the Moon with international capabilities such as the *Lunar Orbital Platform-Gateway* [1] and/or the *Moon Village* [2] among core options, a wide range of mission architectures, concepts of operations, orbital and surface infrastructural components, science and exploration systems - including EVA mobility systems -, are now under consideration for implementation. With the understanding that Mars remains a driving destination for humans to reach and explore in-person by the mid-century time frame, the return to the Moon is an opportunity not only to develop mission architecture elements of use on *both* the Moon *and* Mars, but also to use the Moon as a multifunctional analog in preparation for (to reduce risk at) Mars. We examine here how the Moon may fulfill all four functions of analogs [3], i.e., to help 1) *Learn,* 2) *Test,* 3) *Train,* and 4) *Engage*.

To *Learn* for Mars. Much like terrestrial geologic analogs are used to learn about potential counterparts on the Moon or Mars, the scientific exploration of the Moon is expected help further our fundamental scientific understanding of Mars, in particular its geologic processes, features, and their evolution through time. Impact cratering and volcanism, in particular, are two major geologic processes that have shaped both worlds and left prominent records that may be investigated synergistically. Among key processes and issues, understanding better the impact bombardment history of the Moon and the fate of lunar volatiles will help calibrate the impact and volatile history of Mars, which is key to reconstructing Mars' evolution through time.

To *Test* for Mars: The human return to the Moon also offers opportunities to develop and test new science and exploration technologies, systems, and strategies that may feed forward to enhance the safety and productivity of future Mars exploration. Particularly worth testing on the Moon are approaches and capabilities that are not adequately evaluated on Earth, but that could be matured and demonstrated on the Moon in preparation for Mars. An example of this is the concept of mini rocket-thrustered drones for the exploration of pits and lava tubes on the Moon and Mars [e.g., 4]. Such rocket-thrustered flyers will likely be required for Mars as most lava tubes identified there are located on the flanks of Mars' giant volcanoes, *i.e.,* at altitudes too high for airfoiled flyers to be practical. Such systems would be challenging to test at relevant scales on Earth, but would be ideal for the Moon and could be validated there for Mars.

To *Train* for Mars. The human return to the Moon will offer opportunities to train human crews in the actual practice of living and working on another planetary world, and in the actual implementation of short to long-range planetary surface exploration activities. Experience with long-range Moon and Mars analog pressurized rover traverses on the Haughton-Mars Project on Devon Island, High Arctic, has highlighted the critical importance of building substantial first hand experience with the planning and implementation of such traverses before they can be carried out safely and productively. Pressurized rover traverses on the Moon will be key to the next generation of human explorers advancing lunar science, but also to training future crews for Mars.

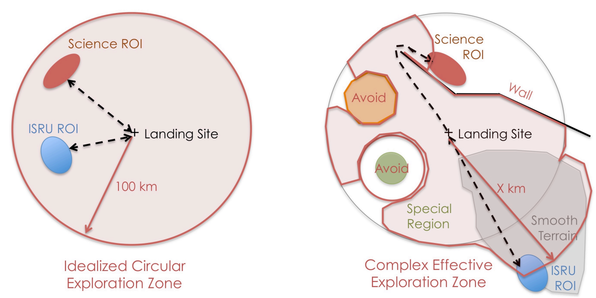

Figure 1. Exploring the Moon and Preparing for Mars. Left: Current planning for the human exploration of Mars uses the concept of a 100 km radius *Exploration Zone* (EZ) around a *Landing Site* (LS). The EZ includes Science and ISRU *Regions of Interest* (ROI). **Right:** In reality, the actual configuration of the accessible EZ around a LS may be more complex, depending in particular on terrain and topography. The human return to the Moon will allow the actual scale and complexities of such EZ models to be experimented with and realistically evaluated, and lessons learned applied to both the Moon and Mars (NASA / P. Lee).

To *Engage* for Mars. The engagement function of an analog relates to its role in inspiring and educating students and the broader public. The human return to the Moon will inevitably, by definition, lack the novelty that the Apollo Program presented. But if cast, and genuinely implemented, as a stepping stone to Mars, the new wave of lunar science and exploration activities will likely be able to maximize and sustain the long-term engagement and support of the public.

References: [1] NASA (2017); [2] ESA/J. Woerner (2016); [3] Lee, P. *et al.* (2005). *CSA CSEW-5*, May 2005. [4] Lee, P. (2018). *ELS-2018*, May 2018.